

As required by the opinion, USBR reinitiated formal consultation with FWS. As a result, FWS identified four actions for immediate implementation:

- Continue to hold the Delta Cross Channel gates open;
- Maintain combined CVP/SWP exports at 2,250 cfs until June 8, 1997;
- Maintain upstream water releases in the American and Sacramento rivers; and
- Maintain an export/inflow ratio of 35 percent.

All but the second item were implemented.

Although these limited actions were taken to reduce delta smelt take at the facilities in late May and early June; combined salvage remained high through early June. In response to con-

tinuing concerns, the flap-gates on the south delta temporary barriers were held open through much of June, and the SWP reduced exports by 1,000 cfs from June 7 through June 11. As part of this reduction in exports, the CALFED Management Team agreed (with concurrence from the SWRCB executive director) to allow an increase in the export/inflow ratio from 35 to 40 percent through the remainder of June as long as delta smelt salvage declined and the center of delta smelt distribution did not move eastward into the delta.

Daily review of delta smelt distribution from the 20-mm and real-time monitoring surveys and the number of delta smelt salvaged per acre-foot at the facilities were used to evaluate whether increased exports would move the center of delta smelt distri-

bution toward the export facilities (Figure 3). However, delta smelt salvage began declining in mid-June, and the center of distribution did not move back into the central delta. In fact, combined salvage moved below the yellow-light level by month's end.

The SWP and CVP were able to maintain an export/inflow ratio of 40 percent throughout the latter part of June, and the south delta temporary barriers became fully operational on June 24. Current accounting estimates of CVP/SWP operations show the actions taken for delta smelt this spring reduced combined exports by 24,000 acre-feet (14,000 in May and 10,000 in June) from base-case operations. However, an additional 48,000 acre-feet was recovered by relaxation of the export/inflow ratio from 35 to 40 percent in June.

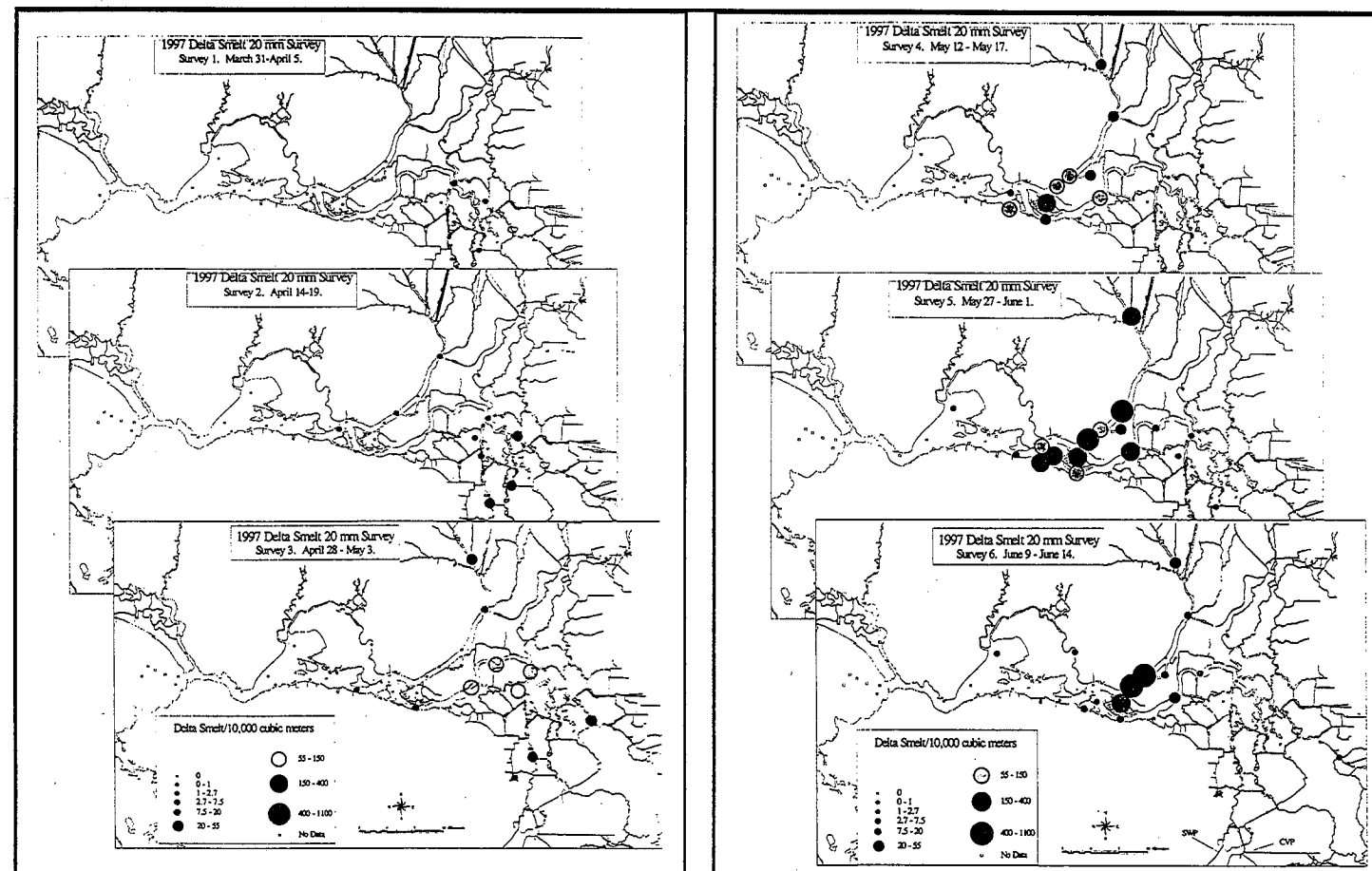


Figure 3
DELTA SMELT DISTRIBUTION AND ABUNDANCE IN THE FIRST SIX 20-MM SURVEYS IN 1997
Circles represent the average density (delta smelt/10,000 m³) at each station sampled three times every 2 weeks.

El Niños and the Decline of Striped Bass

Bill Bennett University of California, Davis, Bodega Marine Lab and
Liz Howard, USBR

Factors causing the decline in the striped bass population after 1976 continue to challenge biologists and restoration efforts (Miller and Foss 1996). Recently, we have been exploring the hypothesis that the decline was initiated by a shift in global climate in 1976-1977 that stimulated migration by older adult striped bass from the estuary to the warmer ocean (Bennett and Moyle 1996). In Atlantic estuaries, oceanic migrations by native striped bass populations are stimulated by seasonally warmer ocean temperatures (Coutant 1985). Our findings provide an additional explanation for previous results, which indicate higher adult mortality, loss of adult egg supply, and poor recruitment have affected the population since 1976 (Stevens *et al* 1985; DFG 1987; Miller and Foss 1996).

Insightful statistical models developed by DFG during the 1960s-1970s (Turner and Chadwick 1972; Stevens 1977) implicated low outflows and water exports (Chadwick *et al* 1977) as the primary problem regulating striped bass year-class success and the population. After 1977, however, year-class success and adult abundance declined more than predicted by these models, directing research on other factors associated with low freshwater outflows affecting primarily young fish in the estuary, including food limitation, predation, and toxic chemicals (Stevens *et al* 1985; Bennett and Moyle 1996). Water exports remain the primary explanation for poor recruitment, long-term loss of adult egg supply, and decline of the population, while the factors contributing to higher adult mortality are unclear (Stevens *et al* 1985; DFG 1987).

Concurrent with the striped bass decline, a shift in global climate in 1976-1977 produced conditions similar to frequent and prolonged El Niño Southern Oscillations (ENSO). This resulted in warmer ocean temperatures (Figure 1), frequent periods of extreme weather (droughts and floods), and substantial changes in the populations of various marine organisms (Peterson 1995; Hayward 1997). The influence of ocean temperature on movements of California's striped bass had been recognized early on by Radovich (1963) during the 1957-1959 ENSO. However, normal (cool) ocean temperatures in the 1960s and the apparent environmental effects associated with exporting higher proportions of fresh water in the 1970s and 1980s drew attention from potential oceanic effects on striped bass (Chadwick 1967; Coutant 1985; Stevens *et al* 1985).

Analyses

We used adult striped bass and egg abundance estimates developed by the DFG mark/recapture program and compiled records from the Commercial Passenger Fishing Vessel (charter boat) survey administered by DFG (Marine Resources Division).

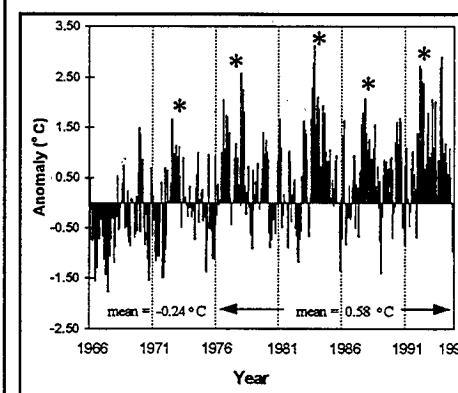


Figure 1
OCEAN TEMPERATURE AT FORT POINT, SAN FRANCISCO (deviations from normal), AND EL NIÑO EVENTS (asterisks)

From the abundance estimates, we calculated cohort decline rates (*ie*, mortality rates) by taking the logarithm of the ratio of age-5 to age-3 and age-7 to age-5 abundance estimates of individual cohorts. We also determined the proportion of total tags returned from the ocean within 3 years after release (analogous to DFG annual harvest rate estimates, Stevens *et al* 1985). From the charter boat survey, we calculated ocean catch per angler effort from two 10-minute latitude-longitude blocks extending from the Marin coastline to Half Moon Bay. Sea surface temperature records were obtained from USGS and the NEMO Oceanographic Data Server from shoreline stations at Bodega Bay, Pacific Grove, and Fort Point/San Francisco administered by NOAA. From these we calculated monthly deviations from long-term monthly averages (anomalies) and annual mean temperatures from May to May so the temperature series would correspond with the striped bass tagging schedule.

We then correlated time series of striped bass population characteristics with ocean temperatures from the three shoreline locations (Table 1). First, we detrended the log-transformed 6-7 and >7 year old abundance estimates (Figure 2a) and temperature time series by computing the difference between successive years. Then the detrended series were cross-correlated at lags of ± 5 time periods. This was done because the appropriate lag in years between when an increase in ocean temperature may be reflected in the abundance estimates is unclear, because the abundance estimates for each year are modified using returns from subsequent years, and some ENSO's

Table 1
SUMMARY OF REGRESSION ANALYSES, R (slope, standard error) OF
OCEAN TEMPERATURE, AND STRIPED BASS POPULATION CHARACTERISTICS

Population Characteristic	Lag (Years)	Sea Surface Temperature Station		
		Fort Point	Bodega Bay	Pacific Grove
Detrended Abundance				
Age 6-7	2	NS	-0.425* (-0.176, 0.078)	-0.483* (-0.129, 0.049)
Age >7	2	-0.456* (-0.130, 0.053)	-0.468* (-0.226, 0.089)	-0.414* (-0.129, 0.059)
Cohort Decline Rate	0	0.583** (0.029, 0.086)	0.585** (0.335, 0.099)	0.660** (0.356, 0.090)
Ocean Catch per Unit Effort	0	0.601** (0.326, 0.139)	0.594** (0.353, 0.147)	NS
Ocean Tag Returns				
Age >7	0	0.559** (0.083, 0.025)	0.475** (0.077, 0.017)	NS

NS = not significant * $P \leq 0.040$ ** $P \leq 0.003$

last more than one year. Additional population time series (Figure 2b, Figure 3) were correlated (at lag=0) with ocean temperature. To assess whether significant correlations may reflect other factors not included in the analyses, we examined autocorrelation functions of residual values from linear regressions.

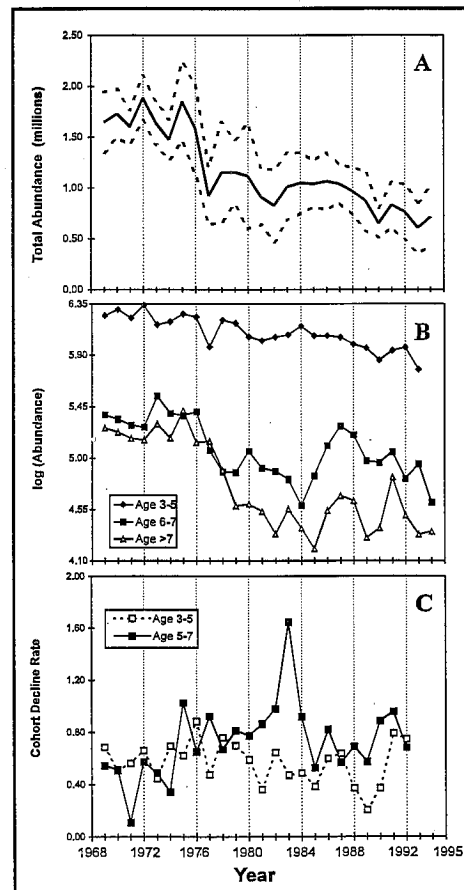


Figure 2
ESTIMATED ABUNDANCE OF
STRIPED BASS POPULATION

Results and Discussion

Substantial changes occurred in the near-shore ocean and striped bass population after 1976. Mean sea surface temperature at Fort Point increased 0.58°C above the long-term average (Figure 1). Estimated total abundance of striped bass declined abruptly (Figure 2a). Comparisons before (1969-1975) and after (1977-1983) the climate shift indicate the

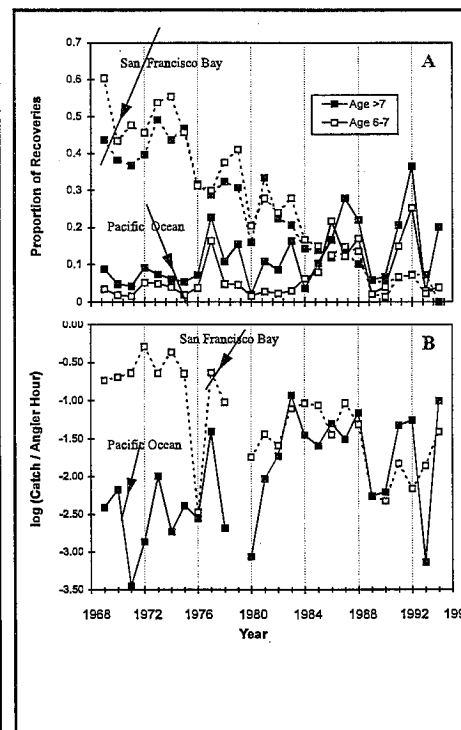


Figure 3
OCCURRENCE OF STRIPED BASS IN
SAN FRANCISCO BAY AND PACIFIC
OCEAN ESTIMATED BY PROPORTIONS OF
TAG RETURNS AND CATCH PER UNIT
EFFORT BY CHARTER BOATS

mean abundance of striped bass declined by 65% for ages 6-7 and 69% for ages >7 years (Figure 2b). Cohort decline rates from age-5 to age-7 increased by 52%, but those for age-3 to age-5 did not increase (Figure 2c). In the ocean, proportions of tag returns increased by 37% for age 6-7 and 48% for >7 year old striped bass; in San Francisco Bay, tag returns for both age groups decreased 60% (Figure 3a). Ocean catch-per-unit-effort also increased by 87% (Figure 3b). These mean changes are significant (Mann-Whitney U's, $P < 0.05$) for all population characteristics except ocean tag returns for 6-7 year olds and ocean catch-per-unit-effort, for which additional comparisons between ENSO years and normal years (Figure 1) are significant (Mann-Whitney U's, $P < 0.05$). These results indicate the decline in striped bass abundance was accompanied by higher decline rates of adult cohorts and the higher occurrence of adults in the ocean after 1976 or during ENSO's.

Cross-correlations are significant for age 6-7 and >7-year-old abundance lagged 2 time periods after ocean temperature (Table 1), and the residuals are not autocorrelated. Additional correlations with ocean temperature are significant using the cohort decline rates, the proportion of ocean

tag returns for >7 year olds, and ocean catch-per-unit-effort, and residual values are not autocorrelated. Correlations using Pacific Grove temperature with ocean catch-per-unit-effort and ocean tag returns are not significant, potentially because temperatures for 1975-1976 are missing, requiring their values to be interpolated. Correlations between ocean temperature and ocean tag returns for 6-7 year olds are also not significant. These results show that positive changes between years in ocean temperature are significantly associated with negative changes in striped bass abundance in the estuary. Moreover, warming ocean temperatures are also significantly associated with higher decline rates of adult cohorts in the estuary, as well as with the higher occurrence of older striped bass in the ocean.

Striped bass egg abundance has also declined substantially (DFG 1987; Miller and Foss 1996). Older females (>7 years old) can produce about 4 times as many eggs as younger (eg, age 5) females (DFG 1987) that are also larger and of higher quality, such that they potentially contribute a high percentage of recruits to the adult population (Rose and Cowan 1993). Egg abundance estimates for age 5-7 females dropped significantly by 52% between the 1969-1975 and 1977-1983 periods, whereas egg abundance of >7-year-old females dropped 70% (Mann/Whitney U, $P < 0.006$). Both egg abundance estimates are correlated with the subsequent abundance of 3-year-olds recruiting to the population (stock/recruit relationships, Figure 4), and the residual values are not autocorrelated. Plotted lines are from geometric mean regressions, which are more appropriate when both the independent and dependent variables contain measurement error. The correlation using older female

(>7 year old) egg abundance explains about twice the variation in subsequent recruitment than the relationship using 5-7 year old egg abundance. This result indicates the higher contribution of older females (>7 years old) to subsequent recruitment of 3-year-olds to the population.

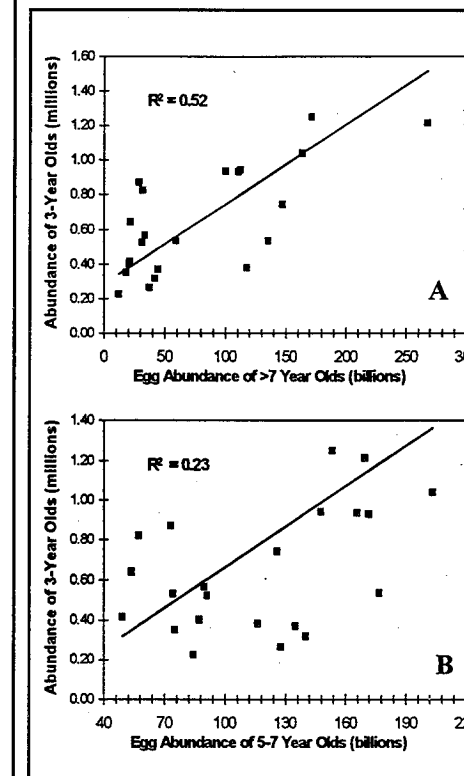


Figure 4
ESTIMATED EGG ABUNDANCE OF
AGE>7 AND AGE 5-7 FEMALES WITH
ESTIMATED ABUNDANCE OF
3-YEAR-OLD STRIPED BASS

Our findings support an alternative scenario for the decline in the striped bass population since 1976. A shift in global climate produced frequent periods of warmer ocean temperatures that stimulated migration to the ocean by many older striped bass. This resulted in a sharp decline in the abundance of older fish, which subsequently contributed to the declining recruitment of 3-year-olds in the estuary. Ocean-going striped bass are caught by the ocean sport fishery, reside in other estuaries, wander in the near-shore ocean, and return in-

termittently to the estuary. Although Atlantic striped bass have traditionally migrated and wandered in the near-shore ocean, the sudden and frequent reversions to such behavior in California initiated a decline in the estuary.

The complex life cycle of striped bass, however, practically ensures other factors are also regulating striped bass abundance in the estuary. In particular, while such clear stock/recruit relationships (Figure 4) are rarely documented for fish populations, striped bass are so highly fecund that the inability of the estuarine population to rebound indicates broad problems for young striped bass in estuary (Stevens *et al* 1985; Bennett and Moyle 1996; Kimmerer *et al* in preparation). Amelioration of such factors may compensate for losses of fish to the ocean. Our future investigations are stimulated by record catches of striped bass now occurring in the ocean as a major ENSO develops.

Literature Cited

- Bennett, W.A., and P.B. Moyle. 1996. Where have all the fishes gone?: Factors producing fish declines in the San Francisco Bay estuary. Pages 519-542, in J.T. Hollibaugh, editor. *San Francisco Bay the Urbanized Ecosystem*. Pacific Division, American Association for the Advancement of Science, San Francisco.
- Chadwick, H.K. 1967. Recent migrations of Sacramento-San Joaquin striped bass populations. *Transactions of the American Fisheries Society* 96:327-342.
- Chadwick, H.K., D.E. Stevens, and L.W. Miller. 1977. Some factors regulating the striped bass population in the Sacramento-San Joaquin estuary, California. Pages 18-35 in W. Van Winkle, editor. *Proceedings on the Conference on Assessing the Effects of Power-Plant-Induced Mortality on Fish Populations*. Pergamon Press, New York.
- Coutant, C.C. 1985. Striped bass, temperature, and dissolved oxygen: a speculative hypothesis for environmental risk. *Transactions of the American Fisheries Society* 114:31-61.

DFG (Department of Fish and Game). 1987. *Factors Affecting Striped Bass Abundance in the Sacramento-San Joaquin River System*. Technical Report 20. Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary. FWQ/BIO-4ATR89-20. DWR, Sacramento.

Hayward, T. 1997. Pacific Ocean climate change: atmospheric forcing, ocean circulation and ecosystem response. *Trends in Ecology and Evolution* 12:150-154.

Miller, L.W., and S.F. Foss. 1996. Low striped bass index for 1996. *IEP Newsletter* 9(4):23-26.

Peterson, C.H., D. Canyon, J. DiLeo, M. Noble, and M. Dettinger. 1995. The role of climate in estuarine variability. *American Scientist* 83:58-67.

Radovich, J. 1963. Effect of ocean temperature on the seaward movements of striped bass, *Morone saxatilis*, on the Pacific coast. *California Fish and Game* 49:191-207.

Rose, K.A., and J.H. Cowan, Jr. 1993. Individual-based model of young-of-the-year striped bass population dynamics. I. Model Description and baseline simulations. *Transactions of the American Fisheries Society* 122:415-438.

Stevens, D.E. 1977. Striped bass (*Morone saxatilis*) year class strength in relation to river flow in the Sacramento-San Joaquin Estuary, California. *Transactions of the American Fisheries Society* 106:34-42.

Stevens, D.E., D.W. Kohlhorst, L.W. Miller, and D.W. Kelley. 1985. The decline of striped bass in the Sacramento-San Joaquin Estuary, California. *Transactions of the American Fisheries Society* 114:12-30.

Turner, J.L., and H.K. Chadwick. 1972. Distribution and abundance of young-of-the-year striped bass, *Morone saxatilis*, in relation to river flow in the Sacramento-San Joaquin Estuary. *Transactions of the American Fisheries Society* 101:442-452.

Noteworthy for Managers

Randall Brown

Here are two examples of programs of possible interest to Interagency Program staff and management.

CVPIA Fish Team

Over the past several weeks a small team of biologists has been grappling with nine actions proposed by the Department of Interior to help increase populations of several anadromous fish using the Sacramento/San Joaquin estuary. Team members include Wim Kimmerer, Marty Kjelson, Roger Guinee, Jim White, Terry Mills, Ken Lentz, Gary Stern, Elise Holland, Chuck Hanson, Serge Birk, Pete Rhoads, and me.

Although the team has made progress defining the actions and designing many of them in the form of tests to better evaluate their contribution to species recovery, there has not been complete agreement on their scientific underpinnings. At the October 8 meeting, the team discussed a process to clarify our understanding of the science behind these and other management actions to protect and enhance fish populations. We agreed that the Interagency Program (perhaps in cooperation with the Modeling Forum) will sponsor one or more workshops to examine X₂ as a management tool. The workshop(s) will probably be held early in 1998. Although we generally agreed to the need for similar evaluations of striped bass and salmon data, we did not agree on a process. Some team members recommended that the Interagency Program conduct these evaluations, but others were not convinced that this was the best forum.

Watershed Protection and Restoration Council

On July 31, 1997, Governor Pete Wilson created the Watershed Protection and Restoration Council, which will be responsible for oversight of State activities to protect and enhance watersheds and the conservation and restoration of anadromous salmonids in California. The council will have a working group (consisting of agency directors and executive officers of Northern California regional water quality control boards and chaired by the SWRCB Executive Officer), a science panel, and three advisory committees. A general program goal it develop a program of California conservation actions that will allow the National Marine Fisheries Service to promulgate a rule that, in effect, allows California to manage the recovery of federally listed anadromous salmonids such as steelhead and coho.

The Watershed Protection and Restoration Council may have direct and indirect effects on the Interagency Program. One direct effect is that Jerry Johns (SWRCB) is deeply involved in the working group and will have less time to devote to IEP activities. The program also includes a requirement to develop a list of recovery and monitoring activities that can protect and conserve anadromous salmonid resources. In the bay/delta and Central Valley, the monitoring could complement existing Interagency Program elements.

Flow Effects and Density Dependence in Striped Bass

Wim Kimmerer, Romberg Tiburon Center, San Francisco State University

Among the numerous challenges facing fisheries scientists are determining causes of long-term trends, assessing environmental effects on populations, and detecting compensatory mechanisms within populations. This report summarizes some of the analyses I have recently conducted to investigate these issues with regard to striped bass in the San Francisco estuary.

Two features of the bay/delta striped bass population are well known: the influence of freshwater flow and diversions on abundance or survival of young, and the long-term decline. The effects of flow during early development on abundance of adult striped bass is evident in data going back to the 1930s (Stevens 1977). Effects on young bass of outflow (Turner and Chadwick 1972) and export flow (Chadwick *et al* 1977) have also been known for a considerable time. Although the mechanism for effects of exports is obvious, that for flow is not. Proposed mechanisms for increased young survival with increased flow include variation of spawning time, inputs of nutrients or organic matter, dilution of toxic substances, reduced settlement of eggs, turbidity effects on visual predation on young bass, and transport to favorable feeding grounds (Turner and Chadwick 1972; Stevens *et al* 1985).

Explanations for the long-term decline have also varied, but in recent years export flows, and consequent entrainment of young fish, have been advanced as the principal cause of the decline (DFG 1987). Although adult mortality has increased during that time as well, the principal mechanism for the decline has been reported as a positive feedback between entrainment, reduced recruitment, subsequently reduced adult abundance

and egg supply, resulting ultimately in still lower young-of-the-year abundance. Bennett and Howard (this issue) offer an alternative explanation: migration of older adults to the ocean has increased since 1977 as a response to generally warmer sea surface temperature, and this migration has reduced the abundance of older, more fecund adults and therefore the egg supply.

Any fish population must have at least one compensatory mechanism to support a sustainable fishery. Compensatory mechanisms or density dependence are most often detected as saturating functions describing the relationship between two successive life stages (most often stock size and recruitment). In the case of a stock-recruit curve, as the spawning stock increases recruitment increases initially, then either levels off (Beverton-Holt curve) or begins to decline (Ricker curve). In either case, there is a restriction in the life cycle that limits the total number of recruits around a maximum called the "carrying capacity". Density dependence may also be detected as a negative relationship between abundance and growth rate, or, less frequently, between abundance and survival or mortality. In the latter case, density dependence is indicated by mortality that increases with increasing population size.

In this report, I present several analyses and draw several conclusions about the decline, the influence of flow and exports, and the effect of density dependence. In contrast to the analyses reported by Bennett and Howard (this issue), I examined only data from within the estuary, and focused mainly on conditions leading up to recruitment at age 3.

Analyses

Striped bass are long-lived and can reproduce repeatedly. Analyses relating abundance of this population to environmental conditions can encounter difficulties with autocorrelation, and results can be difficult to interpret because of the feedback through the life cycle. Therefore I analyzed survival indices (ratios of abundance indices of successive life stages) or mortality (time rates of change of abundance).

Space does not permit a complete exposition of the data used or analyses performed. Briefly, I used a variety of data for various segments of the life cycle of striped bass. These included data on abundance of adults (catch-per-effort data or Petersen estimates based on mark/recapture), adult mortality (based on tag returns), fecundity, abundance of eggs and larvae, and abundance indices and raw data from summer tow-net, fall midwater trawl, San Francisco Bay study, and salvage sampling.

Data analyses focused on the relationship of abundance and survival to flow and evidence for density dependence. Most of the analyses comprised linear regression, in some cases using modern techniques such as robust or tree regression (Venables and Ripley 1994). The analysis was based on explorations of the data using various graphical techniques. Regression and other analyses are reported only if examination of plots of residuals revealed that the assumptions underlying the regression methods were met.

Time Trends

The time course of abundance of adults (Figure 1) reveals three key features. First, all age classes have de-